WE CLAIM AS OUR INVENTION

28) Method of making a silicon penetration device having an increased fracture toughness, comprising the steps of:

providing a silicon substrate for the silicon penetration device, having an initial surface;

heating the silicon substrate to an elevated temperature;

exposing the heated silicon substrate to a series of one or more sequential reactive environments, each containing one or more reactants selected from the group consisting of oxygen, ozone, steam, hydrogen, ammonia, nitrous oxide, nitric oxide and nitrogen;

growing an adherent film of a silicon compound on the initial surface of the silicon substrate during the exposing step, the adherent film formed by a chemical reaction between the reactant or reactants and silicon from the silicon substrate underlying the growing adherent film;

cooling the silicon substrate with the adherent film; and

removing at least a part of the adherent film from the underlying silicon to uncover a new surface on the silicon substrate;

to provide the silicon penetration device having increased fracture toughness.

29) The method of Claim 28, wherein the new substrate surface is smoother than the initial substrate surface for providing the increased fracture toughness of the silicon penetration device.

30) The method of Claim 28, further comprising, before the growing step, the additional step of cleaning the surface of the silicon substrate to receive the adherent film.

31) The method of Claim 30, wherein during the cleaning step, the surface of the silicon substrate is RCA cleaned.

32) The method of Claim 28, wherein during the heating step, the heating is accomplished by a furnace.

33) The method of Claim 28, wherein during the heating step, the temperature is elevated to about 1,100 degrees Celsius.

34) The method of Claim 28, wherein during the exposing step, the heated silicon substrate is simultaneously exposed to multiple selected reactants.

35) The method of Claim 28, wherein during the exposing step, the heated silicon substrate is serially exposed to multiple selected reactants.

36) The method of Claim 28, wherein the growing step is terminated when the adherent film has grown to a thickness of about one micrometer.

37) The method of Claim 28, wherein during the removing step, the adherent film removal is accomplished by an etchant.

38) The method of Claim 37, wherein the etchant is a solution of hydrofluoric acid in water.

39) The method of Claim 28, wherein during the removing step, the adherent film removal is accomplished by etching with a buffered oxide etchant.

40) The method of Claim 28, wherein during the removing step, the adherent film is completely removed to uncover a new surface on the silicon substrate.

41) The method of Claim 28, wherein the adherent film is a silicon oxide compound.

42) Method of making a silicon penetration device having an increased fracture toughness, comprising the steps of:

providing a silicon substrate for the silicon penetration device, having an initial surface;

heating the silicon substrate to an elevated temperature;

exposing the heated silicon substrate to a series of one or more reactive environments containing the reactant or reactants oxygen, steam, or a mixture thereof;

growing an adherent film of a silicon oxide compound on the initial surface of the silicon substrate during the exposing step, the adherent film formed by a reaction between the reactant or reactants and silicon from the silicon substrate underlying the growing adherent film;

cooling the silicon substrate with the adherent film; and

etching away at least a part of the adherent film from the underlying silicon to uncover a new surface on the silicon substrate;

to provide the silicon penetration device having increased fracture toughness.

43) The method of Claim 42, wherein the exposing step further comprises the steps of:

exposing the heated silicon substrate to a reactive environment containing dry oxygen reactant;

exposing the exposed silicon substrate to wet steam reactant; and

exposing the exposed silicon substrate to dry oxygen reactant.

44) The method of Claim 42, further comprising, before the growing step, the additional step of cleaning the surface of the silicon substrate to receive the adherent film.

45) The method of Claim 42, wherein during the exposing step, the silicon substrate is exposed to dry oxygen for about five minutes.

46) The method of Claim 42, wherein during growing step, the reactive environment supports an adherent film growth rate of about forty Angstroms per minute.

47) The method of Claim 42, wherein the growing step is terminated when the adherent film has grown to a thickness of about one micrometer.

48) The method of Claim 42, wherein during the etching step, the adherent film is completely etched away to uncover a new surface on the silicon substrate.

49) A penetration device with increased fracture toughness, comprising:

a silicon substrate which has an initial surface; and

an adherent film of a silicon compound formed on the initial surface of the substrate by silicon from the substrate in chemical reaction with one or more reactants selected from the group oxygen, ozone, steam, hydrogen, ammonia, nitrous oxide,nitric oxide, and nitrogen, which adherent film is at least partially removed to uncover a new surface on the silicon substrate to provide the increased fracture toughness of the silicon penetration device.

50) The device of Claim 49, wherein the adherent film is completely removed to uncover a new surface on the silicon substrate.